Norwegian Space Weather Initiatives

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ABSTRACT

We present some of the space weather initiatives in Norway in the last few years. By space weather initiatives we refer to efforts involving industries that are affected by geomagnetic disturbances, not to the general existing space and solar physics research program, where Norway holds long traditions.

Several scientist at the The Institute of Theoretical Astrophysics are using observations from the Solar and Heliospheric Observatory (SOHO). In addition to the scientific and operational involvements efforts have also been made to present SOHO results to the public. SOHO's capability to detect solar flares and coronal mass ejections has been frequently presented in the Norwegian news media over the last two years. This has made many industries more aware of the influence of solar active phenomena on complex technologies, and we have established contact with a few industrial companies. A seminar on space weather and the impact on electrical power grids was organized by Statnett earlier this year. Statnett, the national Norwegian power grid company, supervises and co-ordinates the operation of the entire Norwegian power distribution system. Their plan is to make detailed measurements of disturbances in the power grids during strong geomagnetic storms this fall to evaluate the effects on their systems.

The Program Board for space science within the Research Council of Norway has recently proposed a new space science program from year 2000 with the emphasis on solar-terrestrial physics. Included in this is an increased focus on space weather applications. The fate of this program will be clear early in 1999.

Key words: Space Weather;.

1. INTRODUCTION

Norway has long traditions both in exploring the Earth's upper atmosphere during geomagnetical storms, and in solar physics research. The location of Norway at high latitudes makes many observation sites well suited for observations of the aurora and magnetic disturbances. Several observatories, both Norwegian and belonging to other countries, run geomagnetic and aurora observatories in Norway. This provides a unique network for the study of the Sun-Earth connection.

However, there have so far been few activities related to what might properly be termed Space Weather and the impacts on man-made installations from solar eruptions. This paper will accordingly focus on some recent initiatives taken toward the space weather users in Norwegian industry, and the status of existing research in space plasma physics and solar physics in Norway, will only be mentioned briefly at the outset.

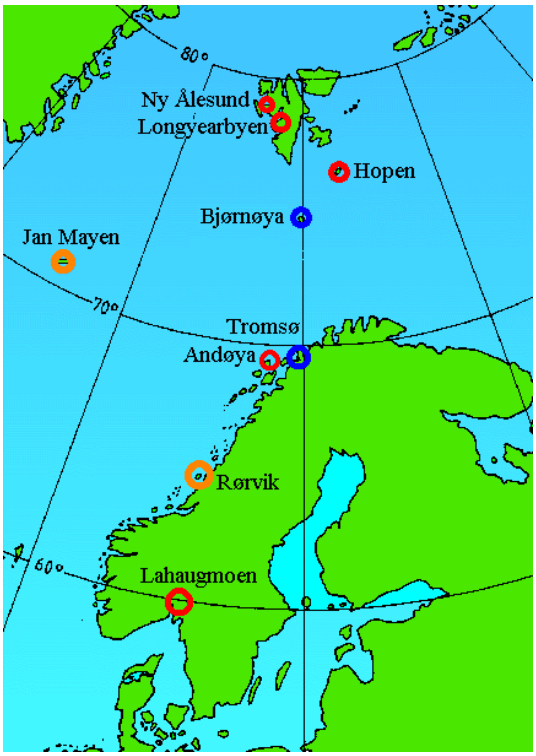

Figure 1. Map showing the geomagnetic observatories (dark circles) and variometer stations (lighter colored circles) operated by the University of Tromsø (Courtesy B. Holmeslet).

2. NORWEGIAN SPACE PLASMA AND SOLAR PHYSICS

The pioneer work executed in Norway by Kristian Birkeland on the aurora and later by Karl Störmer on the radiation belts represents the the start of modern space plasma physics. This work was performed in the early decades of our century and has since been continued and expanded at the universities in Oslo, Bergen and Tromsø. Today there are numerous activities in both observation and modelling of the space plasma surrounding the Earth. One important activity concerns measurements of the magnetic field. Figure 1 illustrates the network of magnetometer stations in Norway operated by the University of Tromsø. Real-time measurements of the magnetic fields are presents via world wide web on this URL: *http://geo.phys.uit.no/geomag.html*. Such measurements will be an important part of space weather activities as a "nowcast" product.

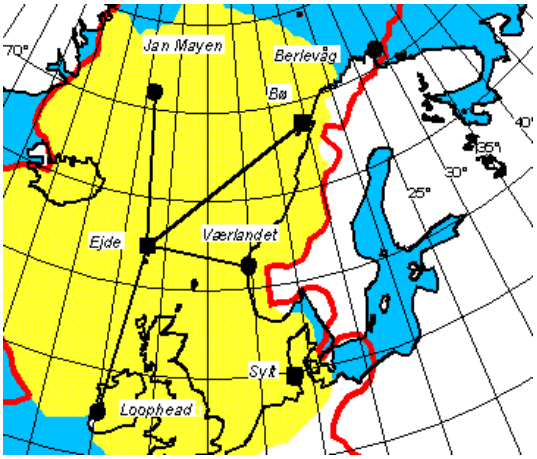

Figure 2. The Northwest European Loran-C System (NELS) where the light shaded area represents the predicted coverage.

Observations of the polar aurora and the ionosphere have also been continued, and have involved Polar Aurora Observatory near Tromsø, EISCAT, science instruments on satellites and on rockets. The scientific sounding rocket programme from the Andøya Rocket Range constitute a major part of the Norwegian Space Program. The Norwegian Space Centre has the overall coordination of all space activities. The major part of the external funding for space research in Norway comes from the Norwegian Research Council.

In solar physics the Institute of Theoretical Astrophysics at the University of Oslo is involved in the successful Solar and Heliospheric Observatory (SOHO). SOHO provides new knowledge about the Sun, but has also become an important solar storm warning satellite. A considerable effort has been made in Oslo to present results from the SOHO satellite to the public. Over the last two years the news media have several times covered SOHO's capability for detecting solar flares and coronal mass ejections. In 1997 we opened a computer display for the public at the institute on the University of Oslo campus, showing the latest images and movies from SOHO. This display was mentioned in the media and turned out to be very popular. All this, including our efforts to inform different companies, has made many industries more aware of many types of interference on complex technologies from solar activity, and we have established contacts with a few companies that will be discussed below.

3. INDUSTRY

In this section we will summarize the initiatives taken towards the industry and where contacts have been established and some collaboration have been proposed.

3.1. The Norwegian Defense Research Establishment

The Norwegian Defense Research Establishment (NDRE) has probably the longest tradition within the field of space weather activities and prediction in Norway. They have been involved in predicting conditions for radio transmission propagation as a service to military and civilian users since the 1950's. They are cooperating in the Doppler and Multipath Sounding Network (DAMSON) in Northern Scandinavia, measuring Doppler spread/shift and multipath spread on HF[1] (3-30 MHz) paths in the auroral zone. In particular they are interested in applications in modem design to optimize transfer of data and in the forecasting of radio wave propagation.

3.2. Norwegian Defense Communications and Data Services Administration

Radio-wave systems like LORAN C are used for navigation and positioning by the Norwegian Defense Communications and Data Services Administration. The Northwest European Loran-C System (NELS) are shwon in Figure 2 where the light shaded area represents the predicted coverage. LORAN C uses large transmitter antennas to send low-frequency (LF) and very-low-frequency (VLF) radio waves, along the ground and off the reflective layer provided by the ionosphere, respectively, to vast distances over land and sea. Loran-C operations are hampered when the sky wave (see Figure 3) arrives at a receiver at the same time as the ground wave. This occurs when the reflecting height of the ionosphere drops, as it does during times of increased activity in the space environment. During the strong geomagnetic storm on November 4 1997 the LORAN C station at Bø in Norway measured deviations in the signals approaching 1000 nanoseconds. This could lead to errors of up to 1 kilometer in positioning. Thus, efficient space weather forecast will add useful information to the LORAN C operators.

[1] HF – high frequency

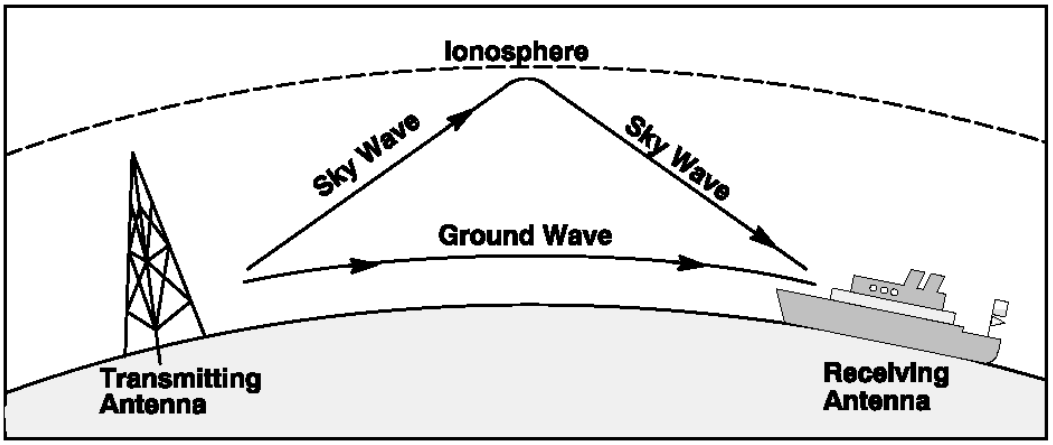

Figure 3. The paths taken by a radiowave transmitted by a terrestrial navigation system like LORAN-C (Courtesy Space Environment Laboratory).

3.3. Statnett - Electric Power Distributor

Induced currents in power lines are well known effects on ground equipment during geomagnetic storms. For this reason we have initiated contact with power companies in Norway, in particular with Statnett. Statnett - the national Norwegian power grid company - do not produce any power. The company's task and responsibility are to transport electricity to its destinations, at all times and at the most reasonable price. Statnett is responsible for the development and operation of the main grid of the Norwegian power supply. Figure 4 shows the power grid in all of Scandinavia, including Norway. The power transmission lines and sub-sea cables connecting Norway to the power systems in Sweden, Denmark, Finland and Russia, are also owned and operated by Statnett. Statnett will have a 50% stake in the proposed sub-sea cables from Norway to Germany and the Netherlands, as well. Statnett coordinates the entire Norwegian power system, monitors the balance between production and consumption of electricity at all times, and oversees that the power grid's capacity is not exceeded. Furthermore, the company owns and operates more than 8,500 km of high-voltage power transmission lines and sub-sea cables, as well as 74 sub-stations and switching stations.

Early in 1998 Statnett organized a small seminar to discuss possible influences on the power grid from geomagnetic induced currents (GIC's). In particular they were to some extent concerned about the planned long subset cables to Europe. These include the EuroKabel (600-800 MW, year 2001) and the Viking Cable (600-800 MW, year 2003). The seminar concluded that the problems should be taken seriously and that Statnett should initiate GIC measurements in the existing power grid to evaluate the effects on their systems. From discussions during the present workshop at ESTEC we will try to establish a close collaboration with the Scandinavian power companies to exchange information. Power companies in both Finland and Sweden have already explored such disturbances and it appears that the power grid in Sweden is more vulnerable to GIC's than the Finnish power grid. The reason may be the use of different types of transformers in Finland and Sweden, according to to Risto Pirjola at the Finnish Meteorological Institute (see this volume).

3.4. Fugro-Geoteam AS

Fugro-Geoteam AS in Norway is a part of Fugro, a multi-national consulting group which provides engineering, consulting and survey services. Fugro's activities are carried out on land, at sea and in the air and include the gathering and interpreting of data and the providing of precise positioning services.

Fugro-Geoteam AS is in charge of seismic explorations surveys where long streamers, cables with attached instrumentation, are towed by vessels to pick up the reflected acoustic waves from air guns to image sedimentary structures below the seabed (see Figure 5). Geomagnetic storms will cause abnormal deviation on the compasses attached to the streamers towed by the vessel, thus jeopardizing the calculation of streamer rotation, which is important to know in order to estimate the coverage in the survey area.

The high precision navigation and positioning services are pursued mainly with differential GPS in conjunction with Fugro-Starfix Europe. The differential GPS system is less affected by variations in the ionosphere compared to stand alone GPS receivers since they are using corrections from onshore reference stations that reflect variations relative to a known position. Another effect of geomagnetic storms is that GPS receivers can loose phase lock on the transmitting satellites making phase measurements in the survey of static networks difficult with the need of extensive post processing to fix the cycle slips. The differential GPS system, which uses pseudo ranges, can be affected, but this is normally just seen as increased noise and thus higher standard deviations in the positions.

Fugro-Geoteam and Starfix are well aware of the problems that can arise during geomagnetic activity and are already utilizing the real-time magnetic measurements from the University of Tromsø in office

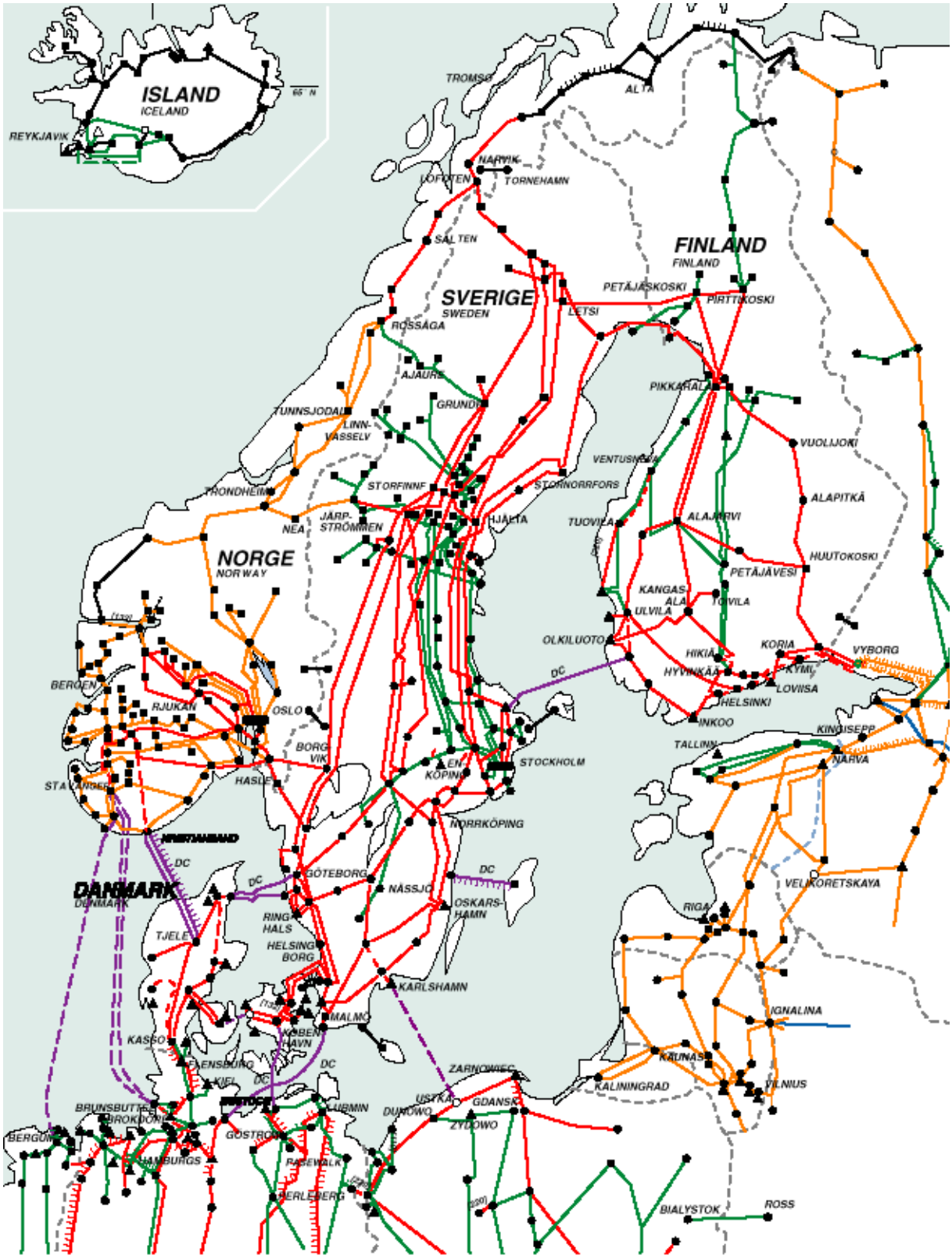

Figure 4. The power grid in Scandinavia. Note the subsea cables to Denmark (black solid lines) and the proposed subsea cables to Germany and Holland (black dashed lines). Source: NORDEL.

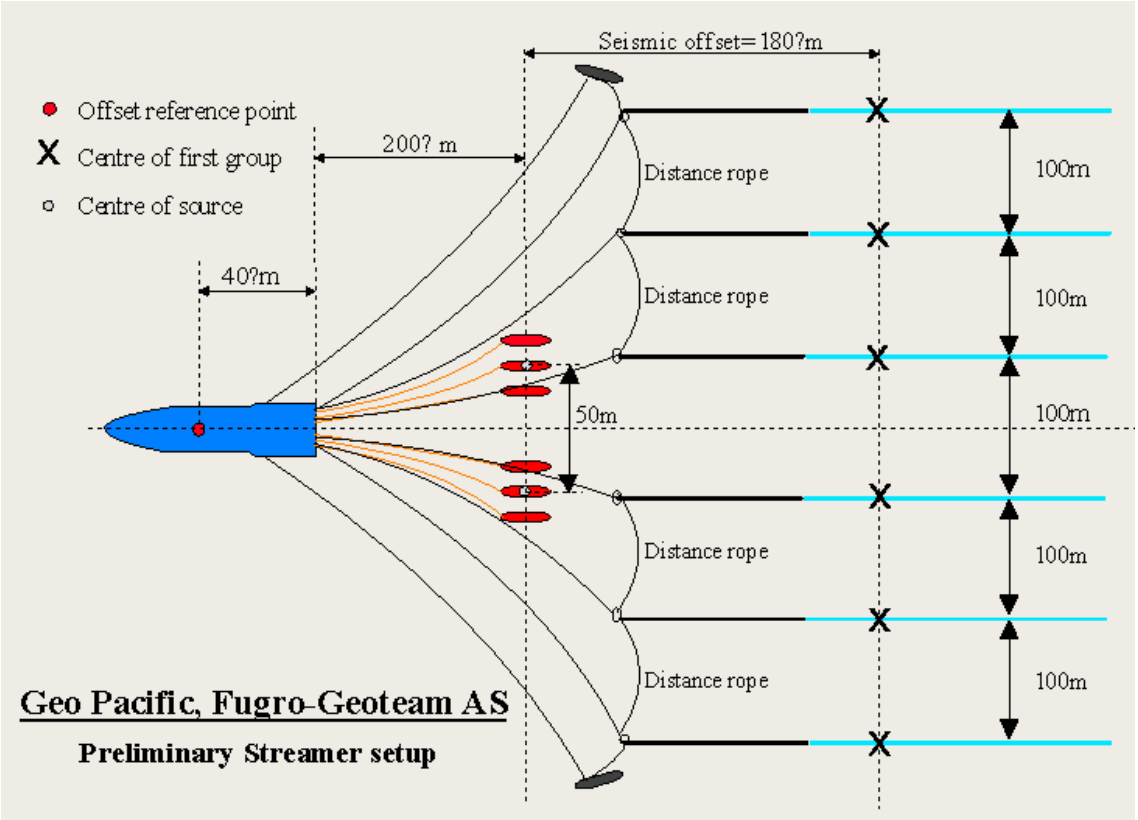

Figure 5. A vessel towing 6 streamers, cables with attached instrumentation which pick up reflected acoustic waves from the air guns to image the sedimentary structures below the seabed. Geomagnetic storms will cause abnormal deviation on the compasses attached to the streamers (Courtesy Fugro-Geoteam AS).

work and on board the vessels. They are also using the solar warning and real-time monitor (SWARM) from the Solar Terrestrial Dispatch. Fugro-Geoteam AS and the Institute of Theoretical Astrophysics will meet late in 1998 to discuss Norwegian space weather initiatives and possible future collaboration in this field.

3.5. Telenor Satellite Services

Telenor Satellite Services (TSS) is responsible for all satellite activities within the Telenor Group. It provides regional and global satellite communications solutions to businesses and consumers. TSS supplies and operates satellite-based products including broadcast services, marine and land mobile communications and satellite network solutions.

Telenor is distributing more than 35 analogue and 70 digital TV channels in the Nordic region, Central and Eastern Europe, plus 30 radio channels. Telenor also distributes Finnish television (FTV) to Europe, as well as national television, NRK International, to Norwegians abroad.

Recently TSS launched their new communication satellite THOR III (see Figure 6) which is operated and monitored from Telenor's new satellite control center in Oslo - by controllers trained at Hughes Space and Communications. Thus, any national space weather forecast would be of interest for the satellite operators. At the moment the operators are warned through their satellite builder Hughes, which again receives space weather information for the Space Environment Laboratory in USA.

3.6. Insurance - the Storebrand Group

Satellite insurance is a relatively new branch of the international insurance business. There are around 20 participating companies of significance world wide. The total insurance capability has increased from USD 350 million in 1991 to USD 1,200 million in 1998. The annual world premium for space risks in 1998 is approximately USD 900 million. The Storebrand Group, one of the major Norwegian insurance companies, covers satellite and general aviation insurance. Storebrand has been part of the satellite market from 1978. In 1997 one of the authors (P.B.) was contacted by Storebrand and asked to give detailed information about space weather. This came as a result of the media presentation of the large solar eruption on January 7 1997, that was followed by a strong geomagnetic storm a few days later. During this storm AT&T's Telestar 401 went silent and it has been suggested that this permanent loss of contact was a result of the geomagnetic disturbances. Storebrand asked us to write a general report on solar eruptions and space weather effects, that was later

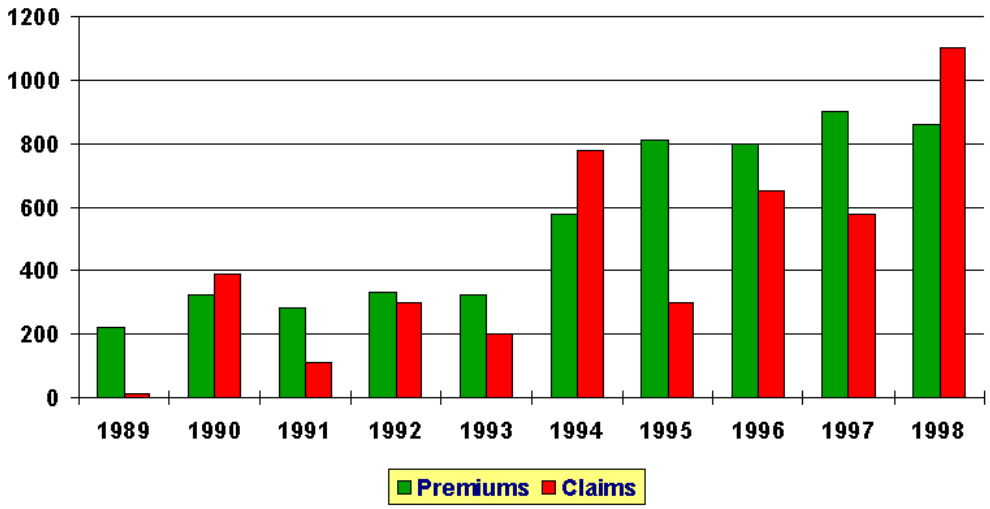

Figure 7. The increase in space insurance since 1989. In 1998 the claims was much higher than the premiums (Source: AON Reinsurance).

Figure 6. Artist's rendering of THOR III in orbit. The satellite was launched on June 9 1998 and is being operated from Oslo, Norway (Courtesy Telenor Satellite Services.

distributed among their customers.

3.7. Storm Weather Center

Storm Weather Center is a new privately owned company providing daily weather forecasting services in Norway. Based on the same raw data as the Norwegian Meteorological Institute (DNMI) they provide weather information to the media, power grid companies, offshore and shipping industry. Examples of their industrial customers are Hydro Energi, Elkem, Hafslund and Oslo Energi. The customers get access to their own customized and updated weather forecast via authorized WWW pages. Another important customer for Storm is TV2, the largest commercial national TV station in Norway. In addition to selling weather forecasts to TV2, Storm is also responsible for the weather presentation and it's layout. Storm has informed the public about several solar eruptions in 1997-98 and forecasted the possibility of aurora a few days later (see Figure 7). Thus, they have played an important role in making the public and the industry aware of these events and the impact they may have on the Earth's environment. Storm has shown interest in distributing space weather forecasts in the future and would like to make this an integrated and important part of their product. Several of their present customers belong to industries that might be affected by the effects of space weather.

3.8. Other users

There are probably other users still to be defined. Listed below are some industries we have not been in contact with yet that could be affected by space weather. The list is based on reported disturbances in similar types of installations in Sweden.

- Oil companies with pipeline network for oil and natural gas (e.g. Statoil, one of the world's largest net sellers of crude oil, and a substantial supplier of natural gas to Europe). Increased corrosion is an effect of geomagnetically induced currents.
- Oil companies with drilling activity where direction is provided by magnetic fields

Figure 8. Video frames from TV2's weather forecast where a solar eruption observed by TRACE on May 19 1998 was presented and compared to the size of the Earth (Courtesy TV2 AS).

- Railway signal systems could be disrupted due to geomagnetic activity (e.g. Norwegian State Railways - NSB)
- Rescue services using radio communication and navigation during rescue operations

4. Future prospects of Space Weather in Norway

The Institute of Theoretical Astrophysics, University of Oslo, is involved in arranging two international meetings, Euroconferences, on space weather. The meetings under the leadership of Observatorie de Meudon in Paris, are financed by the European Community under its programme for Training and Mobility of Researchers. The meetings are aimed at solar physicists and aim to:

- increase the visibility and status of space weather among solar physicists, particularly the young ones,
- encourage the new generation of European solar physicists to work in the field, and to realize that the solar community is not restricted to the often narrow group that they know,
- bring solar physicists together with other groups, e.g. space plasma physicists, industrialists, climatologists,
- encourage cross-fertilization of ideas over a correspondingly wide field,
- secure that solar physics related activities in the field are taken well care of in the future,
- utilize the long term investments in ground-based and space-based solar physics in Europe.

The two workshops will be held in Spain (Tenerife) and Italy (Napoli) in 2000 and 2001, respectively. It is planned to especially invite 30 young researchers for each conference, coming from different countries in Europe. Hopefully the workshop activities will make a long term contribution to making Europe competitive with the US in the field of space weather.

In addition the Programme Board for space science within the Research Council of Norway has recently proposed a new space science program from year 2000 with the emphasis on solar-terrestrial physics. Included in this is an increased focus on space weather applications. The fate of this program will be clear early in 1999. Weather or not Norway should develop it's own space weather forecast program has not yet been discussed in detail. However, it is clear that such a regional center will understand the need of local users better than an international center. Regional centers can respond rapidly to users needs and add value to basic forecasts from larger centers like Space Environment Center in USA.

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